

SELF-CONTAINED SEMICONDUCTOR DEVICE MANUFACTURING  
EQUIPMENT HAVING COMPACT ARRANGEMENT OF LOAD-LOCK AND  
PROCESSING CHAMBERS

BACKGROUND OF THE INVENTION

1. Field of the Invention

**[0005]** The present invention relates to semiconductor device manufacturing equipment. More particularly, the present invention relates to self-contained pieces of semiconductor device manufacturing equipment that are grouped together in a production line.

2. Description of the Related Art

**[0010]** In general, the environment in which semiconductor devices are manufactured must have a high degree of air purity. To this end, the various equipment used to manufacture the semiconductor devices must isolate the products of manufacture from outside sources of pollution and contamination. Furthermore, certain pieces of the manufacturing equipment must be positioned near each other in the production line if the line is to be compact and to operate efficiently. For instance, those pieces of equipment performing the same process should be grouped together, and pieces by which sequential processes are carried out on a wafer should be grouped together. Such a disposition of semiconductor

device manufacturing equipment in a production line is schematically shown in Fig. 1. Referring to this figure, the respective pieces of manufacturing equipment are installed on a working line portion 2 of a production line 1, and a plurality of pieces of manufacturing equipment 4 that perform the same process are arrayed in a line along a bay 3 in which a worker is free to move.

[0015] Today's semiconductor device manufacturing equipment must perform more functions than ever to meet the demand for more highly integrated semiconductor devices. Thus, the incorporation of such manufacturing equipment into an existing production line tends to require a greater amount of area than that which was occupied by the outdated manufacturing equipment. That is, the incorporation of new manufacturing equipment into an existing production line expands the space requirements in both the X-axis and Y-axis directions shown in Fig. 1. In particular, modernized manufacturing equipment if merely incorporated into an existing production line would invade the installation area of the existing equipment 4 within the limited space of the production line 1. Accordingly, some of the various pieces of the manufacturing equipment 4, which are to carry out respective processes having a mutual correlation, could be removed and installed in another production line 1. However, such a reconfigured production line would delay the overall process by which a semiconductor device is manufactured from a wafer, i.e., would be subject to time delays and cost increases.

[0020] Furthermore, when an error in one process manifests itself as a manufacturing defect in a subsequent process, the severity of the defect will only increase as the process progresses. Such a problem is thus associated with reductions in manufacturing yield.

[0025] Semiconductor manufacturing equipment for performing processes such as chemical vapor deposition, etching, diffusion, metallic deposition, has been developed to overcome such problems. This conventional manufacturing equipment typically includes a plurality of process chambers, load lock chambers and auxiliary chambers, which are connected by a transfer chamber and are controlled by a controller.

[0030] The conventional multi-chamber structure of such a piece of manufacturing equipment 4 will now be described in more detail with reference to Figs. 1, 2a and 2b. At least one load lock chamber 10a, 10b faces the bay 3 in which technicians are free to move. The load lock chambers 10a, 10b are used to isolate the inside of the remainder of the equipment from the external environment of the production line. A respective cassette K accommodating a plurality of wafers W may be loaded into or taken out of the load lock chambers 10a, 10b through doors 22a, 22b disposed at one side each of the load lock chambers 10a, 10b. Furthermore, the inside of the load lock chambers 10a, 10b is maintained under a vacuum by a vacuum-pressure unit (not shown) operated as timed to the loading and unloading of the cassette K therefrom. The other side

of each of the load lock chambers 10a, 10b is selectively connected to a transfer chamber 12. A robot R is provided in the transfer chamber 12 and has an arm 18 for transferring the wafers W between respective positions as required. Also, a plurality of process chambers 14a, 14b for performing a main process (etching, chemical vapor deposition, diffusion, sputtering etc.) on the wafers W are connected to the transfer chamber 12. Finally, an auxiliary chamber 16 for performing pre- and post- processing operations for the main process, such as cooling, drying, cleaning, inspecting operations, is also connected to the transfer chamber 12. Up to now, the semiconductor device manufacturing equipment having the multi-chamber structure described requires an installation area that is acceptable to some extent.

[0035] However, space considerations are still sometimes problematic when trying to incorporate such semiconductor manufacturing equipment into an existing production line. The installation area required may be rather wide due to the fact that the respective chambers 10a, 10b, 14a, 14b, 16 are spaced from one another in a width-wise direction of the transfer chamber 12. Furthermore, because the respective chambers 10a, 10b, 14a, 14b, 16 are spaced from one another in the width-wise direction of the transfer chamber, the transfer chamber 12 and the working envelope of the robot arm 18 must be rather large in the width-wise direction. In particular, as the number of functions provided by the manufacturing equipment increase, the larger the equipment tends to become in

the width-wise direction. Accordingly, in some instances when manufacturing equipment having a multi-chamber structure of this type is too wide, pieces of the manufacturing equipment having a common purpose must be installed in a separate and independent production line. This, of course, gives rise to additional expenses including those associated with managing another production line. Such expenses increase the unit price of the semiconductor devices. Thus, the conventional multi-chamber type of semiconductor manufacturing equipment presents serious problems in connection with modernizing or increasing the capabilities of an existing production line.

#### SUMMARY OF THE INVENTION

**[0040]** Accordingly, an object of the present invention is to substantially obviate one or more of the limitations and disadvantages of the prior art.

**[0045]** More specifically, a primary object of the present invention is to provide semiconductor device manufacturing equipment which can be installed within a small area in a semiconductor device production line, whereby a plurality of pieces of equipment that perform the same process and a plurality of pieces of equipment that are mutually concerned with the production of a semiconductor device may be provided within the limited space of a single production line.

**[0050]** Another object of the present invention is to provide semiconductor device manufacturing equipment that can contribute to the efficiency of a

semiconductor device production line, whereby the expenses associated with manufacturing the semiconductor devices may be curtailed.

**[0055]** A still further object of the present invention is to provide semiconductor device manufacturing equipment which makes it easy to change the layout of a production line.

**[0060]** To achieve these objects, the present invention provides a self-contained piece of semiconductor device manufacturing equipment having a plurality of working chambers that are arrayed at least vertically, a transfer chamber to which each of the working chambers is connected, and a robot for positioning and transferring the wafers disposed in the transfer chamber.

**[0065]** The working chambers can include a plurality of process chambers for performing a process on the wafer, and one or more load lock chambers. Each load lock chamber has a first door leading to the outside, i.e. to the production line, and a second door leading to the transfer chamber.

**[0070]** The plurality of process chambers may be arrayed vertically one side of the transfer chamber, and a plurality of load lock chambers may arrayed vertically on another side of the transfer chamber directly across from the process chambers, respectively. Alternatively, a plurality of process chambers and a load lock chamber can all be disposed in one vertical array on one side of the transfer chamber. As another alternative, the transfer chamber may be disposed above a load lock chamber, with a plurality of process chambers being disposed in a

vertical array at one side of the transfer chamber.

**[0075]** In addition, some of the working chambers may be arrayed horizontally in addition to vertically at one side of the transfer chamber. Still further, a vertical array of working chambers may be disposed as horizontally offset from one another, i.e., may be disposed in a stepped configuration, at one side of the transfer chamber.

**[0080]** Furthermore, the robot includes at least one robot arm having a working range that encompasses the various chambers of the equipment. To this end, the robot arm/arms may be articulated about/along an axis/axes and/or driven in rotary, horizontal and/or vertical directions. The end of the robot arm is constituted by a wafer support for grasping a wafer.

**[0085]** In the case in which a plurality of load lock chambers are disposed in a vertical array at one side of the transfer chamber, an indexing mechanism is provided for the loading/unloading of a wafer cassette into/from any one of the load lock chambers. The indexing mechanism preferably comprises a shelf and a sensing unit for sensing that the cassette is positioned stably thereon, an elevator for raising and lowering the shelf alongside the load lock chambers and positioning the shelf in response to an applied transfer control signal, a sliding transfer unit for selectively inserting and withdrawing the cassette into and from a load lock chamber according to the state of the door of the load lock chamber, and a controller for controlling the elevator and sliding transfer unit.

[0090] The aforementioned objects can also be achieved by providing semiconductor device manufacturing equipment in which a plurality of wafer support members are disposed side-by-side in each of the working chambers, and the end of the robot arm comprises a plurality of wafer supports capable of simultaneously supporting a plurality of wafers, the number of wafer supports corresponding to the number of wafer support members disposed in each of the working chambers. Accordingly, the robot can transfer a plurality of wafers at one time to and from each of the working chambers.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0095] These and other objects, features and advantages of the present invention will become clearer from the following detailed description of the preferred embodiments thereof made with reference to the accompanying drawings, of which :

Fig. 1 is a schematic diagram of a production line showing the disposition of a plurality of pieces of manufacturing equipments within the line;

Fig. 2a is a schematic plan view of a conventional piece of semiconductor device manufacturing equipment having a multi-chamber structure;

Fig. 2b is a sectional view of the semiconductor device manufacturing equipment as taken along line A-A' of Fig. 1;

Fig. 3 is a schematic plan view of a first embodiment of semiconductor

device manufacturing equipment according to the present invention;

Fig. 4 is a schematic plan view of a second embodiment of semiconductor device manufacturing equipment according to the present invention;

Fig. 5 is a schematic plan view of a third embodiment of semiconductor device manufacturing equipment according to the present invention;

Fig. 6 is a longitudinal sectional view of the first embodiment of semiconductor device manufacturing equipment as taken along line VI - VI of FIG. 3;

Fig. 7 is a cross-sectional view of the first embodiment of semiconductor device manufacturing equipment as taken along line VII - VII of FIG. 3;

Fig. 8 is a cross-sectional view of the second embodiment of semiconductor device manufacturing equipment as taken along line VIII - VIII of FIG. 4;

Fig. 9 is a cross-sectional view of the second embodiment of semiconductor device manufacturing equipment as taken along line IX - IX of FIG. 4, showing an alternative arrangement of the main process and auxiliary chambers;

Fig. 10 is a longitudinal sectional view of the first embodiment of semiconductor device manufacturing equipment as taken along line X - X of Fig. 5;

FIG. 11 is a cross-sectional view of semiconductor device manufacturing

equipment according to the present invention, having an indexing mechanism and a robot that includes two robot units;

FIG. 12 is a cross-sectional view of still another embodiment of semiconductor device manufacturing equipment according to the present invention;

FIG. 13 is a cross-sectional view of yet another embodiment of semiconductor device manufacturing equipment according to the present invention; and

FIG. 14 is a longitudinal sectional view of a still further embodiment of semiconductor device manufacturing equipment having a robot that includes a branched wafer support according to the present invention .

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0100]** The preferred embodiments of the present invention will be described below in detail with reference to the accompanying drawings. Note, like reference numeral designate like parts throughout the drawings. Furthermore, arrows are used throughout the drawings to show the directions in which the components of the robots of the various embodiments may be articulated and driven.

**[0105]** A first embodiment of the semiconductor device manufacturing equipment will now be described with reference to Figs. 3, 6 and 7. The

semiconductor device manufacturing equipment comprises a housing and a plurality of main process chambers 32a, a plurality of load lock chambers 34a, and a plurality of auxiliary process chambers 36a, and a transfer chamber 30a disposed in the housing. Of these respective working chambers, the main process, load-lock and auxiliary process chambers 32a, 34a and 36a are arrayed vertically, as best shown in Figs. 6 and 7. More specifically, the process chambers 32a, 36a are disposed in a vertical array at one side of the transfer chamber 30a, whereas the load lock chambers 34a are disposed in a vertical array at the other side of the transfer chamber 30a. The chambers are also connected to the transfer chamber 30a of the semiconductor device manufacturing independently of each other through respective doors 22b and 22c (FIG. 3). Doors 22a connect the load lock chambers 34a to the environment outside the equipment.

**[0110]** A robot Ra having a robot arm is disposed in the transfer chamber 30a for positioning the wafers W relative to and transferring the wafers W between the respective working chambers 32a, 34a and 36a. The terminal end of the robot arm comprises wafer support member 18 for supporting (e.g., grasping) a wafer W as the wafer W is being transferred by the robot Ra.

**[0115]** In addition, the supply lines 38a of various types of units, such as vacuum and gas supply units, are disposed across from the respective chambers to which they are connected, in the longitudinal direction of the equipment as

opposed to the width-wise direction.

**[0120]** Thus, the self-contained piece of semiconductor device manufacturing can be installed even in a narrow space.

**[0125]** In the embodiment shown in Figs. 4, 8 and 9, each of the process chambers 32b, 36b is connected to a respective load lock chamber 34b via the transfer chamber 30b. Furthermore, in this array of working chambers, a number of the process chambers 32b, 36b can be disposed next to each other in a horizontal row (to the right and left of each other) at one side of the transfer chamber 30b. For instance, as shown in the figures, two of the main process chambers 32b are arrayed horizontally (in a row) at one side of the transfer chamber 30b, and two corresponding load lock chambers 34b are arrayed horizontally (in a row) at the opposite side of the transfer chamber 30b. In the version shown in FIG. 8, the auxiliary process chamber 36b is disposed above the row of main process chambers 32b. Alternatively, as shown in FIG. 9, the row of main process chambers 32b may be disposed above the auxiliary process chamber 36b. Supply lines 38b are connected with these respective chambers 32b, 36b.

**[0130]** In the embodiment shown in FIGS. 5 and 10, a plurality of the process chambers, namely the main process chambers 32c and an auxiliary process chamber 36c, are disposed one above the other at one side of the transfer chamber 30c as in the previous embodiments. A respective load lock

chamber 34c is disposed across from each of the process chambers 32c, 36c with the transfer chamber 30c interposed therebetween. However, in this embodiment, the respective process chambers 32c, 36c can be arranged in a stepped configuration, i.e., are disposed as horizontally offset from each other in the longitudinal direction (to the left and right in FIG. 10) of the equipment. In particular, the process chambers 32c, 36c are disposed offset from each other in a horizontal direction corresponding to the direction in which they are spaced from said transfer chamber

[0135] Meanwhile, according to another aspect of the invention as shown in Fig. 11, the robot comprises a plurality of robot units Ra1, Ra2 disposed in the transfer chamber 30d, each having a robot arm comprising a wafer support member 18. Each of the robot units has a working range that encompasses at least two of the working chambers (e.g., the main process chambers 32d and auxiliary process chamber 34d) that are disposed vertically adjacent each other at one side of the transfer chamber 30d, as well as the corresponding chambers (e.g., the load lock chambers 34d) disposed horizontally across therefrom at the other side of the transfer chamber 30d. In this way, some of the wafers W may be processed at an upper position, while others of the wafers W are processed at a lower position.

[0140] Additionally, the semiconductor manufacturing equipment may also comprise an indexing mechanism 40 for transferring a cassette K received from

the production line 1 to a respective load lock chamber 34d under the direction of a controller. The indexing mechanism 40 includes a shelf 42, and an elevator 44 for raising and lowering the shelf 42 in response to transfer control signals issued by the controller. The shelf 42 is equipped with a sensing unit S for sensing whether a cassette K is disposed stably at a predetermined position on the shelf 42. The indexing mechanism 40 also includes a sliding transfer unit 46 for selectively loading and unloading the cassette K into and from a load lock chamber once the first door 22a of the load lock chamber 34d has been opened.

**[0145]** The aforementioned controller may control the driving of the elevator 44 and the sliding transfer unit 46 on the basis of the sensed state (open or closed) of the first doors 22a of the load lock chambers 34d.

**[0150]** In one form of operation, the cassette K is stably positioned on the shelf 42 of the indexing mechanism 40, and the shelf 42 is transferred to a position at which the cassette K may be handed over to a technician in the bay of the production line or to a position at which the cassette K may be transferred to or from a load lock chamber 34d. In the latter case, the door 22a of the load lock chamber 34d is opened as triggered by the driving of the elevator 44 in response to a transfer control signal issued by the controller. The controller then issues a control signal to the sliding transfer unit 46, causing the transfer unit 46 to slide along the shelf 42 into the open load lock chamber whereupon the cassette K is loaded into or unloaded from the load lock chamber 34d.

[0155] In the embodiment of Fig. 12, the working chambers, i.e., the plurality of process chambers and load lock chambers 32e, 34e and 36e, are disposed vertically at one side of the transfer chamber 30e. A controller (not shown) confronts the load lock chamber 34e or the process chamber 32e.

[0160] Furthermore, in this embodiment, the robot Rb comprises a support shaft 50 that extends vertically through the entirety of the transfer chamber 30e, and a robot arm mounted thereto. More specifically, the robot arm comprises a moving shaft 52 mounted to the support shaft 50 so as to be capable of ascending/descending and rotating therealong, and an extendable/retractable arm member 54 supported on the moving shaft 52. The arm member 54 positions the wafer support member 18 horizontally relative to the working chambers 32e, 34e and 36e. That is, the arm member 54 extends or withdraws the wafer support member 18, and the wafer support member is itself horizontally extendable and retractable relative to the arm member 54 to load a wafer W into or withdraw a wafer W from an open one of the chambers.

[0165] In the embodiment of Fig. 13, the load lock chamber 34f is connected to the bottom of the transfer chamber 30f, whereby wafers W are withdrawn from the top of the load lock chamber 34f into the transfer chamber by a robot Rc. The robot Rc has a robot arm comprising a fixed arm support 56, a movable arm support 58 mounted to the fixed arm support 56 so as to be horizontally movable relative thereto in directions toward and away from the

process chambers 32f, 36f, an arm member 54 mounted to said movable arm support 58 so as to move therewith, and a wafer support member 18 mounted to the arm member 54 by a driven joint 60 capable of rotating the wafer support member about a horizontal axis. The arm supports 56, 58 are disposed at the top of the transfer chamber 30f directly above the door 22b of the load lock chamber 34f.

**[0170]** The arm member 54 of the robot Rc is extendable and retractable in the vertical direction so as to enable the wafer support 18 to be moved toward and away from the load lock chamber 34f. Accordingly, the robot Rc is capable of loading wafers into and unloading wafers from the load lock chamber 34f. Furthermore, the arm member 54 is also movable in horizontal directions, via the movable arm support 58, so that the wafer support 18 can be moved toward and away from selected ones of the process chamber 32f. The arm member 54 is also rotatable relative to the arm supports 56, 58. Still further, the wafer support 18 can be rotated about a horizontal axis via the joint 60, and can be extended and retracted relative to the end of the robot arm member 54. Accordingly, the robot Rc is also capable of loading wafers W into and unloading wafers W from each of the process chambers 32f, 36f.

**[0175]** Finally, according to another aspect of the present invention shown in Fig. 14, the working chambers, namely the main process chamber 32g, the load lock chamber 34g and the auxiliary process chamber 36g, can each

accommodate multiple wafers side-by-side. In this case, each of the working chambers has a plurality of wafer supports 32a, 32b, 34a, 34b and 36a, 36b at which a plurality (two, in this case) of wafers are supported side-by-side.

Furthermore, the robot arm of the robot Rd disposed in transfer chamber 30g has a plurality of wafer support members 18a, 18b for simultaneously grasping a number of wafers W corresponding to the number of wafers that can be accommodated side-by-side in each of the working chambers 32g, 34g and 36g. In this case, the wafer support member 18a, 18b are integral and constitute a branched wafer support arm.

[0180] Accordingly, even with this embodiment, the required installation area is comparatively small, and more processing space is provided per unit area in comparison with the prior art. because a plurality of the wafers W can be processed concurrently within each of the process chambers, the efficiency of the production line is enhanced.

[0185] As is evident from the detailed description above, in accordance with the present invention, at least some of the working chambers of the semiconductor device manufacturing equipment are disposed one above the other, or wafer supports are provided side-by-side in the working chambers to thereby minimize the floor area required for installing the equipment. As the direct result of such space savings, more pieces of manufacturing equipment that are mutually concerned with the same aspect of the manufacturing process can be

installed together within the same production line.

[0190] In addition, pieces of the manufacturing equipment can be arranged within the production line to prevent the processing of the wafer from stagnating at any one point, and to otherwise enhance the efficiency of the production line. Hence, the costs of running the production line and the manufacturing equipment is kept in check, to thereby curtail the unit price of the products.

[0195] Additionally, the layout of semiconductor manufacturing equipment in the production line can be changed when needed due to the compactness and flexibility offered by the equipment according to the present invention. That is, the production line can be used to it's maximum extent.

[0200] Finally, various changes to and variations of the present invention will become readily apparent to those skilled in the art. Thus, all such changes and modifications that come within the scope of the appended claims are seen to be within the true spirit and scope of the invention.